GREENHOUSE GAS EMISSIONS AND CARBON FLUX

FROM

HYDROPOWER RESERVOIRS IN INDIA

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by

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Dedicated

to

My Loving Children

Ushnik & Ushniha

CERTIFICATE

This is to that the thesis entitled "**Greenhouse Gas Emissions and Carbon Flux from Hydropower Reservoirs in India**" submitted by **Mousumi Nath** to the Indian Institute of Technology, Delhi India, for the award of the Degree of **Doctor of Philosophy** in Civil Engineering is a bonafide record of original research work carried out by her under our supervision in conformity with the results and regulations of the Institute.

The research reports and results presented in this thesis have not been submitted in part or full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

Energy is the lifeline of any developing country, like India. Power sector development consisting hydropower is the core of its development policy. Considering the multi-fold benefits of hydropower e.g. Renewable, inflation free, higher efficiency (over 90%) compared to thermal (35%)and gas (around 50%), lower Cost of generation, operation and maintenance etc., its development is inevitable.

However, issue of greenhouse gas emissions from Hydropower reservoirs has been raised on various national and international platforms. Several studies have been done in this regard in countries like North America, Canada, and Brazil etc. They reveal that an interplay of various factors like the topography, climate, soil and geological conditions as well as land-use, reservoir operations etc. are the factors responsible for the ultimate fate of carbon in the reservoirs. There are several scientific uncertainties and complexities involved in the matter as the study/research done on the issue is still in a preliminary state. A better understanding of the CH_4 footprint of tropical reservoirs is also required.

The study of greenhouse gas emissions from the hydro power reservoirs in India is at a nascent stage. Only fewer studies like measurements done by Scientists of the CSIR-National Institute of Oceanography in eight dams-reservoirs. India is a signatory to the United Nations Framework Convention on Climate Change (UNFCC). That said, India is increasingly engaged in reducing carbon emissions and alleviating environmental degradation.

In the backdrop of the above scenario, the present research was undertaken to close the knowledge gaps and develop a better understanding of the process of GHG emissions from Hydropower reservoirs, in India.

Measurements usually made at specific point/time do not account for the transient nature of reservoir C flux and the heterogeneity in flux that occurs across different types of ecosystems inundated with water. Therefore, a process based model with proven track record was used to understand the emission characteristics of the reservoirs in India.

The research involved study of characteristics and distribution of hydropower reservoirs in India to give a comprehensive picture of the greenhouse gas emissions from them. The

research involved estimation of Power Density (i.e. watt per sq.m area for Dams of National Importance (i.e. dams with height 100 m and above or with storage capacity of 1Km^3 and above completed). This was done in line with the threshold criteria developed by the CDM Executive board of UNFCC.

The thesis deals with the estimation of greenhouse gas emissions and carbon flux from five different hydropower reservoirs in India located in different climatic conditions and having different characteristics using a process based model Wetland DNDC. The model was used after validation using Model Evaluation Techniques for comparison of the simulated and measured values.

Five case studies, representative of the country as a whole have been carried out i.e. Sardar Sarovar, Gujarat; Govind Sagar (Bhakra Nangal Dam) Himachal Pradesh; Supa, Karnataka; Gumti, Tripura and Govind Bhallabh Pant Sagar (Rihand Dam), Uttar Pradesh.

The model study helped in identifying the influencing parameters that play a vital role in deciding the fate of emissions from hydropower reservoirs. It has also revealed the range of GHG emissions that various hydropower reservoirs might experience in different parts of the country through representative case studies.

The model reveals the impact of climate change caused by variation in the temperature, rainfall etc. upon the GHG emissions from hydroelectric reservoirs through sensitivity analysis. The model also gives the effect of net emissions (i.e. NEE) due to the construction of hydroelectric reservoir apart from the impact of the GHG emissions on account of inundation of the surrounding land area.

Thus, in a country like India of continental proportion, use of process based model with proven track record can be greatly be helpful in closing our knowledge gaps and understanding the emission characteristics due to inundation on account of hydroelectric projects. This would assist in better planning and implementation of the hydropower projects in an informed and clean manner.

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NOTATIONS AND ABBREVATIONS

NOTATIONS

m	meter
W	Watt
MW	Megawatt
GW	Giga watt
TW	Terawatt
TWh	Terawatt hour
ha	Hectare
MT	Mega tonne
t	Metric ton
µM	Micro Molar(moles/litre)

ABBREVATIONS

BGL	Below Ground Level
CD	Cumulative Density
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CWC	Central Water Commission
D	Depth of water table
DIC	Dissolved Inorganic Carbon
DOC	Dissolved organic Carbon
ES	Potential Soil Evapotranspiration
ET	Potential Evapotranspiration
FC	Field Capacity
GHG	Greenhouse Gases
GOI	Government of India
GPP	Daily Gross Photosynthesis
GWP	Global Warming Potential
HEP	Hydroelectric Project
IHA	International Hydropower Association
IMD	Indian Meteorological Department
JD	Julian day

K	Light extinction coefficient
LAI	Leaf Area Index
Max.	Maximum
Min.	Minimum
MOWR	Ministry of Water Resources
NEE	Net Ecosystem Exchange
NGL	Near Ground Level
NO_x	Mono nitrogen oxides
NPP	Net Primary Productivity
NRLD	National Register of Large Dams
NSE	Nash-Sutcliffe efficiency
OM	Organic Matter
P_a	Partial pressure of air
PBIAS	Percent bias
PD	Power Density
P_{int}	Plant Interception
PS	Porosity
P_w	Partial pressure of water
R	Rainfall
r	Pearson's product-moment correlation coefficient
R2	coefficient of determination
RLD	Root Length density
RMSE	Root mean square error
RSR	RMSE-observations standard deviation ratio
SSD	Sardar Sarovar Dam
STDEV	Standard deviation
SW	Soil moisture
T	Temperature
TP	Potential plant Evapotranspiration
WT	Water table position
WTD	Water Table Depth

LIST OF APPENDIXES

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